RESEARCH PAPER

A comparative cost analysis for using compost derived from anaerobic digestion as a peat substitute in a commercial plant nursery

Adriana P. Restrepo¹, José García García², Raúl Moral¹, Fernando Vidal³,
María D. Pérez-Murcia¹, María Á. Bustamante⁴, and Concepción Paredes¹

¹Departamento de Agroquímica y Medio Ambiente, Universidad Miguel Hernández
EPS-Orihuela, ctra Beniel Km 3.2, 03312-Orihuela (Alicante), Spain.

²Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario (IMIDA),
C/ Mayor, s/n. 30150 La Alberca (Murcia), Spain

³Departamento de Economía Agroambiental, Ing. Cartográfica y Expresión Gráfica en la Ingeniería,
Universidad Miguel Hernández
EPS-Orihuela, ctra Beniel Km 3.2, 03312-Orihuela (Alicante), Spain.

⁴Departamento de Conservación de Suelos y Agua y Manejo de Residuos Orgánicos, Centro de Edafología
y Biología Aplicada del Segura, CSIC, PO Box 164, 30100 Murcia, Spain.

Abstract

A.P. Restrepo, J. Garcia-Garcia, R. Moral, F. Vidal, M.D. Pérez-Murcia, M.A. Bustamante, and C. Paredes. 2013. A comparative cost analysis for using compost derived from anaerobic digestion as a peat substitute in a commercial plant nursery. *Cien. Inv. Agr.* 40(2): 253-264. The aim of this study was to evaluate the economic feasibility of using compost made from anaerobically digested cattle slurries in a commercial nursery. Using a comparative cost analysis, commercial peat substrate growing media has been partially substituted with increasing proportions of compost (25, 50 and 75% v/v of compost). This experiment was intended to establish the conditions under which the use of these composts is feasible and competitive relative to commercial peat, at both agronomic and economic levels. Neither the quality of germination nor the vegetative development of the seedlings selected for the experiment (tomato, melon and pepper) were compromised, which was a necessary condition of peat substitution. In addition, the economic effects of using alternative compost media instead of peat alone have been quantified. The results showed that the most suitable scenario from an agronomic standpoint is to substitute 25% of the peat with compost because higher proportions of compost in the growing media are more limiting, especially for the tomato crop. At an economic level, reductions of up to 43% of the substrate cost and a 4.6% improvement in the commercial contribution margin for a company in this sector resulted from 50% peat substitution.

Key words: Anaerobic digestion, costs, economics, growing media, peat, seedling production.

Introduction

Peat is the main component of plant growing media in the European Union (Bohlin, 2002; Schmilewski, 2009). In addition, it constitutes

one of the principal raw materials used in the soilless crop production sector in both cells and containers. Peat is used for producing quality seedlings with the aim of establishing morphological and physiological assurance of successful crop development following the transplant process (Lazcano *et al.*, 2009). The Spanish horticultural sector is mainly focused on soil-based

crop production. However, soilless cultivation is increasing more and more because close to 80% of the growing media used in Spain is made of peat-based materials, mainly *Sphagnum*. In recent years, concern about the environmental impact associated with peat extraction (Larcher and Scariot, 2009) has increased; despite the fact that peatlands only cover 3% of the terrestrial and freshwater surface of the earth (Maltby and Proctor, 1996), they accumulate one-third of the soil C in the world (Joosten and Clarke, 2002, Turunen *et al.*, 2002, Schaller and Kantelhardt, 2009). Thus, peatland exploitation implies a potential source of C emissions, which could greatly influence climate change (Boldrin *et al.*, 2010; Mäkiranta *et al.*, 2010; Bullock *et al.*, 2012). In addition, peat is not an autochthonous resource in southern Europe, where a significant soilless crop production sector is found. Peat must therefore be imported, leading to greater and greater expenses, and, notably, a heterogeneous composition (Ribeiro *et al.*, 2007). Peatlands in Spain are very scarce (60,000 tons) (USGS, 2012), and most peat is imported (170,000 tons in 2010) (IGME, 2010). The use of peat and the increasing growing media industry in the European Union is estimated to be worth 1.3×10^3 million € and generates approximately 11,000 jobs (EPAGMA, 2012). Industry dependence on this sector implies fluctuating prices (Figure 1), but with a clear increasing trend (an increase of

13.2% in the median price was observed during the 2006-2010 period), depending on the scarcity of this material and its non-renewable nature, which could result in a loss of competitiveness for the nursery and greenhouse growing sector in relation to soilless substrates. Several governments are trying to reduce the use of peat as a substrate and soil improver, as well as encouraging the re-use of organic wastes as substrate components instead of disposing of them (Moral *et al.*, 2009). Therefore, the partial or complete substitution of peat with high quality compost is an increasing need (Tittarelli *et al.*, 2003), and it is important to reduce the cost of these mixtures without diminishing their quality (Abad *et al.*, 2001; Fitzpatrick, 2005). However, the use of compost as a substrate and/or substrate component can also have certain limitations, mainly in relation to physico-chemical and/or physical restrictions. Some of these restrictions are high salt content (Ribeiro *et al.*, 2000; Sánchez-Monedero *et al.*, 2004; Castillo *et al.*, 2004), unsuitable physical properties (Raviv, 1998; Spiers and Fietje, 2000) and variable quality and composition (Hicklenton *et al.*, 2001). However, using compost mixtures with peat can minimize these negative characteristics (Raviv *et al.*, 1986). Therefore, testing different compost proportions in the growing media is essential for reducing potential hazards, especially salinity (Bustamante *et al.*, 2008).

Figure 1. Peat imports to Spain (Personal compilation based on IGME, 2010).

On the other hand, anaerobic digestion is gaining interest as a biological method of managing the increasing amounts of organic wastes generated by livestock production. This treatment generates two products, namely biogas containing methane (CH_4) and a digested material by-product (digestate) (Restrepo *et al.*, 2013). However, although the digestate has potential as a fertilizer, it can also present some undesirable characteristics, such as odor, in association with high volatile fatty acid contents, viscosity, high humidity and potential phytotoxicity and pathogenic micro-organisms (Teglia *et al.*, 2011). Composting the solid fraction of the digestate can be a feasible method not only for managing these materials but also for improving the quality of the end-product. Composting the solid fraction reduces odor emissions (by decreasing the concentration of volatile compounds) and also reduces the moisture content and potential phytotoxicity, which in turns contributes to the elimination of pathogens (Bustamante *et al.*, 2012). Different studies have shown that the composts derived from anaerobic digestates can be used as growing media instead of peat because they present similar physical, physico-chemical and chemical properties to those of peat (Bustamante *et al.*, 2008; Moral *et al.*, 2009). In fact, solid anaerobically digested cattle slurry with maize/oat silage has a good auto-composting capacity (Bustamante *et al.*, 2012). In addition, the compost could develop good properties as a growing medium (Restrepo *et al.*, 2013). The balance between compost and peat for use in soilless crop production at both environmental and agronomic levels is therefore something of an art. However, little information is currently available regarding the real economic feasibility of these alternatives for the commercial production of horticultural products in an environment in which the cost of inputs is increasing, especially the prices of growing media with its high energy dependence associated with a specific nature or transport. These conditions support the redesign of soilless production systems that are now mainly based on the use of peat and in areas with a high external dependence, such as

the Mediterranean basin, where the selection of a peat substitute is conditioned by cost and the availability of alternative material (Larcher and Scariot, 2009). Therefore, decisions must be based on economic criteria (García García and García García, 2011).

The aim of the present study is to perform a cost analysis of using anaerobically derived digested cattle slurry composts for commercial seedling production. Using a comparative analysis, this experiment attempts to establish the conditions under which the study composts are feasible and competitive relative to commercial peat for producing seedlings of three horticulturally significant plant species (tomato, melon and pepper). Additionally, the potential positive economic effect of using compost as an alternative to peat alone has also been quantified.

Materials and methods

An agronomic validation for substituting peat with compost

This viability study is based on experiments in which increasing proportions of peat were substituted with compost in growing media for three significant horticultural crops (tomato, melon and pepper). This compost was produced from the solid fraction of a commercial digestate by anaerobically co-digesting cattle slurry with cattle manure and maize-oat silage in an industrial digester located at a dairy cattle farm. The compost was produced by a Rutgers static pile composting system under forced aeration and a controlled temperature, in a pilot composting plant belonging to the Miguel Hernández University (EPSO), located in Orihuela (Alicante, Spain; 38° 5' 8" N, 0° 56' 49" W, elevation 23 m a.s.l.)". More details about its elaboration has been presented elsewhere (Bustamante *et al.*, 2012). The bio-oxidative composting phase lasted 95 days and after that, the mixture was allowed to mature for one month. This compost was mixed

in increasing proportions (25, 50 and 75% v/v) with commercial peat, and pure peat was used as the control treatment. The main characteristics of compost and peat are shown in Table 1. According to different criteria suggested in the literature (Bernal *et al.*, 2009), the compost showed a good degree of maturity, as well as suitable physical properties for use as a substrate.

Three different vegetable species were used to verify if the increasing proportion of compost in the growing medium was influencing commercial parameters such as the germination rate and biomass production. The vegetable species were selected in relation to their salt-sensitivity according to Maas (1986), with a less sensitive tomato (*Lycopersicon esculentum* Mill.), a moderately salt-sensitive melon (*Cucumis melo* L.) and the most salt-sensitive species was pepper (*Capsicum annum* L.). The experiment was carried out in a standard commercial nursery under regular operating conditions, with growing media placed in trays, germination periods in ambient-controlled

chambers and management within the greenhouse until the seedlings reached commercial transplant size (Restrepo *et al.*, 2013).

Economic evaluation of the established substitution scenarios

To carry out an economic evaluation of the substitution alternatives, only scenarios in which the agronomic results were statistically similar to those obtained with control commercial peat substrate were used. Cost accounting has been used (Layard and Glaister, 1994; Ballester, 2000; Romero *et al.*, 2006) to carry out a cost analysis of the digestate-derived compost alternative substrate. The economic assessment is based on a comparative analysis among alternatives and thus does not include fixed costs, *e.g.*, the infrastructure depreciation cost, managerial staff, etc., because it considers these costs similar among all the options, accepting that the use of alternative substrates do not establish changes

Table 1. Main characteristics of peat and compost.

Parameter	Peat	Compost
Physical properties		
Bulk density (g/cm ³)	0.13	0.22
Shrinkage (%)	15.5	11.7
Air capacity (%)	51.9	39.1
% Easily available water	13.9	5.00
Physico-chemical properties		
Cation exchange capacity (cmol/kg organic matter)	140	155
pH	5.97	6.92
Electrical conductivity (dS m ⁻¹)	0.44	7.52
Chemical properties		
Organic matter (%)	82.5	65.9
Total organic carbon (g kg ⁻¹)	405	324
Total nitrogen (g kg ⁻¹)	10.9	31.4
P (g kg ⁻¹)	0.62	8.20
K (g kg ⁻¹)	2.00	19.7
Ca (g kg ⁻¹)	59.0	86.0
Mg (g kg ⁻¹)	12.5	9.20
Na (g kg ⁻¹)	3.06	7.10
Fe (g kg ⁻¹)	2.17	2.55
Cu (g kg ⁻¹)	19.2	69.4
Mn (g kg ⁻¹)	84	159
Zn (g kg ⁻¹)	43	250

in the fixed costs. All operations were considered self-financing in order to avoid introducing financial variables.

First, the total variable production cost was established (which is included in the cost of the working assets), including the average variable cost of each 1000 seedlings as a production unit. Data and values obtained from different sources were used (public organizations from both the research and management fields, private companies from the horticultural seedling sector and local associations of producers). The cost structure has been calculated depending on the additional consulting from four representative companies in the horticultural seedling sector with a similar production level. The correct application of analysis methodology requires information on the production structure of companies; thus, it is essential to establish the specific characteristics of the representative companies in the study area (García García *et al.*, 2012). The analysts made observations for half a year at full production, including the data from the collaborating companies and data from the general productive process of public institutions in the Region of Murcia (Agrarian Regional Offices and Integrated Centers of Training and Agrarian Experiences from the Council of Agriculture and Water). This information was obtained by carrying out interviews “*in situ*” in three stages (a. open interviews with the farmers; b. questionnaires; and c. audits and validations of the information with specific questions directed to the interviewees). The opportunity costs (Samuelson and Nordhaus, 1995) have been calculated as the next-best alternative use of working capital in risk-free financial assets. An interest rate of 2.0% was assumed, depending on the current cost of money and the inflation adjustment. The production variables obtained from the interviews and shown in Table 2 have been used to calculate costs and incomes. The relative importance of the cost of the substrate has been quantified by using the total variable cost, and the production unit value has also been determined.

Table 2. Productive variables used in the feasibility study.

Item	Value
Output level (plants year ⁻¹)	167,000,000
Greenhouse surface (m ²)	55,000
Trays (number of cells)	150- 216- 294- 384
Useful life of trays (years)	4
Average capacity of cells (cm ³)	16.5
Type of peat	Peat 80-20 <i>Sphagnum</i> moss
Peat consumption (m ³ year ⁻¹)	2,749 m ³
Average price of peat (€ m ⁻³)	37
Employment level (number of employees)	20
Water consumption (m ³ ha ⁻¹ year ⁻¹)	7,273
Price of water (€ m ⁻³)	0.20
Gross incomes (€ year ⁻¹)	1,462,320
Average incomes (€ per 1000 plants)	8.76

It is common for customer to provide seeds to the commercial nursery; in cases in which the nursery provides the seeds, the costs are directly transferred to the customer. Therefore, the total gross annual incomes have been calculated without considering the seeds. The gross income and total variable costs can be calculated by using the Contribution Margin (CM), which is the margin used before considering depreciation and fixed costs. CM is calculated by taking the difference between the gross incomes (GI) and the incremental costs or variable costs (IC).

The break-even point indicates the minimum price of the substrate (€ m⁻³) under which the alternative substrate is profitable in relation to the substrates in current use. From this break-even point, the evolution of the average cost of the substrate in relation to the alternative substrate price (peat substitution with digestate-derived compost in the selected scenarios depending on their agronomic behavior) has been analyzed. Finally, the evolution of the average variable cost, the savings in peat costs and the consequent increment in the commercial Contribution Margin for a company representative of the nursery sector have been addressed.

Results and discussion

Substituting peat with compost

Seed germination rates for the three selected horticultural crops are shown in Figure 2. In melon and pepper, seed germination was not statistically influenced by the percentage of compost incorporated into the media, even for the 75% substitution v/v with compost. This result indicates an absence of phytotoxicity in the growing media to these species.

However, adding compost decreased tomato seed germination, which was the only 25% peat substitution in which negative effects were not observed. This substitution result is usually reported as a safe or conservative substitution level, *e.g.*, in most of the experiments that use different types of compost, substituting 25% of the peat with these composts does not induce lower germination in the study crops (Moral *et al.*, 2012).

Biomass was used as an indicator of the agronomic efficiency of these substitutions, and the fresh weights of aerial plant parts were analyzed at the time of sale. The evolution of this parameter is shown in Figure 3. Considering all the substitution scenarios, the 25% treatment achieved the same biomass production, *e.g.*, the same appearance and vegetative development, as the pure peat control treatment, which is the most common commercial substrate. However, when the proportion of compost in the substrate increased, this parameter showed clear decreases

(Figure 3). When this result is combined with a decrease in germination efficiency, it can be concluded that peat substitutions with this type of compost should be considered as follows: the optimum treatment using the 25% substitution in the three study crops and a riskier scenario with a 50% substitution, which is only viable for melon and pepper.

Cost analysis

The first cost analysis result is the establishment of the cost structure of a standard company representative from the intensive horticultural seedling production sector, which is characteristic of the Spanish Mediterranean area. This structure is shown in Table 3, in both absolute and relative terms, and it corresponds to a commercial nursery with production variables as indicated in Table 2.

The labor costs are the primary costs for this activity at a quantitative level, representing 59% of the total variable cost. In southeastern Spain, the crops that create more employment per unit area are the horticultural crops grown under greenhouse conditions, specifically 2.4 Number of Agricultural Jobs (NAJ) ha⁻¹ (MAGRAMA, 2012). This activity is most similar to the employment requirements associated with horticultural seedling production in nurseries. Peat consumption is the next most important factor and is responsible for 20% of the costs. There are several published analyses of the growing media sector, which have quantified the consumption of peat and other substrates in

Figure 2. Germination rate of select horticultural species according to the peat-compost substitution rate (P: peat, C: compost).

Figure 3. Aerial biomass production of study horticultural species according to the peat-compost substitution rate.

Table 3. Cost accounting for a representative company.

Costs/Incomes	Absolute cost (€)	Relative cost (%)
Labor cost (€ year ⁻¹)	299,268	59.2
Cost of irrigation water (€ year ⁻¹)	8,000	1.6
Fertilizers (€ year ⁻¹)	6,480	1.3
Phytosanitary measures (€ year ⁻¹)	32,400	6.4
Energy (€ year ⁻¹)	12,178	2.4
Peat (€ year ⁻¹)	101,719	20.1
Vermiculite (€ year ⁻¹)	10,260	2.0
Trays (€ year ⁻¹)	35,640	7.0
Total incremental cost (€ year ⁻¹)	505,944	100

Europe and particularly in Spain (Altmann, 2008; Paappanen, 2010; IPTS, 2011). From these data, we know peat is the primary growing medium and covers 99% of the total media consumption in Spain. The main subsectors are floriculture (438,000 m³) and horticulture nurseries (175,000 m³), relative to a 2008 total of 875,000 m³. The average ex-works price of peat is 33.46 € m⁻³ in the internal European market, reaching 40 € m⁻³ if non-professional uses are included (Altmann, 2008).

There are very few economic studies about the use of alternatives to commercial substrates in professional horticulture production; however, there are reports about the market and the prices of peat and other substrates (EPAGMA, 2012; IPTS, 2011). Because compost from anaerobic digestate is an innovative material, establishing the cost of this product can be tackled from two points of view, that is, by internalizing all the production costs in the product price or by revising the market to establish the retail price of similar products. In biogas production plants, digestate is considered to be a waste instead of a by-product, with a potential price of 3-5 € ton⁻¹ (IPTS, 2011). IPTS (2011) established the cost of the composting process as 20-60 € ton⁻¹ according to the technology used, but the price of compost in bulk is much lower and is mainly related to transport costs, which increases the price to approximately 5 € ton⁻¹. If these costs are unified, the resulting price ranges between 28 and 70 € ton⁻¹. There is a range of prices in the Spanish market, but if we consider compost in bulk, the average

reference value would be around 25 € ton⁻¹, which is close to the low range of the calculated cost and will be used as a reference value in this study. To make the prices of peat and compost equal, we must express them in € m⁻³; compost presents a bulk density of 0.22 g cm⁻³ (Table 1) and thus, 25 € ton⁻¹ is equivalent to 5.5 € m⁻³.

Economic indicators of productive activity have been calculated to analyze the current situation and the partial peat substitution alternatives. The current peat substrate price determines the break-even point of the alternative substrates; in this data analysis, we established the price at 37 € m⁻³ (Table 2). Therefore, the alternative substrates must have a lower cost for consideration as feasible alternatives from an economic point of view.

As established by the agronomic analysis portion of this study, the economic study is focused on the following two scenarios: optimum substitution at 25% for the three study crops and a riskier scenario with 50% compost substitution, which is only viable for melon and pepper. Figure 4 shows the evolution of the average substrate cost depending on the price established for compost in substitutions of 25 and 50%, which correspond to the values in Table 4. The use of compost with lower prices than those of peat could notably decrease the average cost of the growing media used in nurseries, especially with peat substitutions of 50%. When substituting 50% of the peat with compost, and considering the estimated price for compost (5.5 € m⁻³), this substitution would imply a change in the cost from 0.62 a 0.352 € 1000 ud⁻¹, which yields a

42.9% reduction in the cost of the substrate and 20.6% in the case of the most conservative scenario (25% substitution with compost). It is fundamental to note that compost is a by-product of livestock waste and biogas production and it can be given a value and, therefore, a stable market price with an assured and stable supply.

Table 5 shows an analysis of the economic influence that comes from saving on the cost of peat within the cost structure of the specific standard company as a representative of the relevant sector (Table 1). The price of compost notably influences the total substrate cost and consequently affects the unit variable cost and the total variable cost. In view of the most advantageous alternative established here (with a 5.5 € m⁻³ compost price

and peat substitution at 50%), the variable cost would decrease from 3.05 to 2.92 € 1000 ud⁻¹. This decrease in the variable cost would have a direct effect on the contribution margin of the representative company, which would change from 952,242 € to 996,407 €. In this case, the business contribution margin would increase by 4.6% for the most advantageous scenario and by 2.3% for the most suitable 25% substitution alternative. This value can be low and does not justify a production strategy change at the business level in some cases, but the result is important because it demonstrates that these solutions are feasible from an economic point of view at this time. Depending on other conditioning aspects, such as an increase in the cost of peat and the energy associated with its transport, together with potential regulatory and legal factors that reduce the use of peat in Spanish and European territories and even worldwide, the progressive substitution of peat with compost for germination and propagation activities in horticultural nurseries is clearly preferred. In addition, this analysis must be combined with the progressive internalization of the environmental costs of peat.

Then describes the most important conclusions. The substitution of peat with compost derived from the anaerobic digestates of cattle slurries and manures has been shown to be a feasible alternative from an agronomic and economic

Figure 4. Average cost of alternative substrates depending on the compost price under consideration.

Table 4. Average cost of alternative substrates based on the price of compost.

Price of compost (€ m ⁻³)	Average cost of substrate 25% (€ per 1000 units)	Average cost of substrate 50% (€ per 1000 units)
0	0.47	0.31
5	0.49	0.35
5.5	0.49	0.36
10	0.51	0.39
15	0.53	0.44
20	0.55	0.48
25	0.57	0.52
30	0.59	0.56
35	0.61	0.60
37 ¹	0.62	0.62
40	0.63	0.65

¹37 € m⁻³ is the current price of peat and therefore has no effect on the cost of alternative substrates.

Table 5. Economic indicator values based on the price of compost.

Price of compost (€ m ⁻³)	Incremental cost (€ per 1000 units)		Total cost of substrate (€ year ⁻¹)		Total incremental cost (€ year ⁻¹)		Contribution Margin (€ year ⁻¹)	
	25%	50%	25%	50%	25%	50%	25%	50%
0	2.90	2.74	77,815	51,877	484,140	458,201	978,180	1,004,119
5	2.92	2.79	81,320	58,887	487,645	465,212	974,675	997,108
5.5	2.92	2.79	81,671	59,588	487,995	465,913	974,325	996,407
10	2.94	2.83	84,825	65,897	491,150	472,222	971,170	990,098
15	2.96	2.87	88,330	72,908	494,655	479,232	967,665	983,088
20	2.98	2.91	91,836	79,918	498,160	486,243	964,160	976,077
25	3.00	2.95	95,341	86,928	501,665	493,253	960,655	969,067
30	3.02	3.00	98,846	93,939	505,171	500,263	957,149	962,057
35	3.05	3.04	102,351	100,949	508,676	507,274	953,644	955,046
37 ¹	3.05	3.05	103,753	103,753	510,078	510,078	952,242	952,242
40	3.07	3.08	105,856	107,959	512,181	514,284	950,139	948,036

¹37 € m⁻³ is the current price of peat and therefore has no effect on the cost of alternative substrates.

perspective when substituting 25% for selected horticultural crops; a 50% substitution presented certain risks in relation to the tomato crop.

The feasibility of these two alternatives is conditioned by the price of compost and depends on different factors, but under the current conditions of the Spanish market, the cost of growing medium for each 1000 seedlings can be reduced by 20% to 43%, which would increase the commercial CM in a standard company by 4.6% for the most favorable scenario. Therefore, without accounting for external environmental factors, the feasibility of this option seems to be clear for anaerobic digestate compost from livestock wastes.

Acknowledgements

This work was financed by the Spanish Ministry of Science and Innovation (current Ministry of Economy and Competitiveness) as part of the Plan Nacional I+D+I 2008-2011, and European Regional Development Funds (FEDER, “Una manera de hacer Europa”) through “Proyecto Singular Estratégico Probiogas”. The contract for Dr. Bustamante has been supported by a ‘Juan de la Cierva’ (MCINN, Spain) grant in collaboration with European Social Funds. The authors also wish to thank Semilleros El Raal-Cox S.L. and Babyplant S.L. for their help in the practical development of this study.

Resumen

A.P. Restrepo, J. Garcia-Garcia, R. Moral, F. Vidal, M.D. Pérez-Murcia, M.A. Bustamante y C. Paredes. 2013. Análisis de costes comparativo del uso de compost derivados de procesos de biometanización en sustitución de turbas en semilleros hortícolas comerciales. Cien. Inv. Agr. 40(2): 253-264. El objeto del presente estudio fue evaluar la viabilidad económica de compost derivados de la biometanización de estiércoles vacunos en su uso en semilleros hortícolas comerciales. Mediante un análisis comparativo se ensayaron dosis crecientes de sustitución compost-turba (25, 50 y 75%, expresado en volumen), frente al medio de turba comercial. Se pretende establecer las condiciones en las que el uso del compost

propuesto es viable y competitivo frente al uso de turbas comerciales, tanto a nivel agronómico como económico. Se establece como condición necesaria en las estrategias de sustitución la inexistencia de disminución de la calidad de la germinación y del desarrollo vegetativo de las plántulas de los cultivos seleccionados para el ensayo (tomate, melón y pimiento). También se ha cuantificado el efecto económico que tendría en una explotación comercial representativa el uso del sustrato alternativo mezcla, frente al uso exclusivo de turbas que actualmente se realiza. Como principales resultados se ha obtenido que el escenario más idóneo a nivel agronómico se sitúa en el 25% de sustitución de la turba, siendo más limitante tasas de sustitución superiores, especialmente para el cultivo de tomate. A nivel económico se pueden alcanzar reducciones de hasta el 43% del coste del sustrato con un incremento de hasta un 4,6% del margen bruto comercial de una empresa tipo para la sustitución de turba en un 50%.

Palabras clave: Costes, digestión anaerobia, económica, medios de cultivo, producción de plántulas, turba.

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